Nearshore Canyon Experiment

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Grant numbers: N00014-02-10145 & N00014-02-10484

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Grant number: N00014-02-1 0415
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LONG-TERM GOALS

The long-term goals are to understand the transformation of surface gravity waves propagating across the nearshore to the beach, the corresponding wave-driven circulation, and the associated evolution of surfzone morphology.

OBJECTIVES

The objective of the Nearshore Canyon Experiment (NCEX) is to understand the effect of complex continental-shelf bathymetry on surface gravity waves and on the breaking-wave-driven circulation onshore of the irregular bathymetry. A primary objective this year was execution of the observational phase of NCEX. Additional objectives of our research are to test hypotheses for nearshore waves, currents, and morphological change with previously obtained observations.

APPROACH

Our approach is to test hypotheses by comparing model predictions with waves, currents, and morphological evolution observed on natural beaches.

WORK COMPLETED

Infragravity motions observed with 5 alongshore arrays of current meters and pressure gages deployed for 4 months during the SandyDuck experiment were analyzed (Noyes *et al.*, 2004, Noyes *et al*. *in review*).

Surfzone drifters were used in studies of nearshore circulation (William Schmidt thesis dissertation research, Schmidt *et al., in review*).
Friction coefficients in the swash were estimated with observations from vertical stacks of current meters (Raubenheimer *et al.* 2004).

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 2004**	2. REPORT TYPE	3. DATES COVERED **00-00-2004 to 00-00-2004**
4. TITLE AND SUBTITLE **Nearshore Canyon Experiment**		5a. CONTRACT NUMBER 5b. GRANT NUMBER 5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)		5d. PROJECT NUMBER 5e. TASK NUMBER 5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Woods Hole Oceanographic Institution, MS #11,,Woods Hole,,MA,02543**		8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)		10. SPONSOR/MONITOR'S ACRONYM(S) 11. SPONSOR/MONITOR'S REPORT NUMBER(S)
12. DISTRIBUTION/AVAILABILITY STATEMENT **Approved for public release; distribution unlimited**		
13. SUPPLEMENTARY NOTES		
14. ABSTRACT		
15. SUBJECT TERMS		

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**8**	

Standard Form 298 (Rev. 8-98)
Prescribed by ANSI Std Z39-18

Field observations and numerical model results were used to investigate the formation of cusps on a natural beach (Ciriano *et al., in review*), and the effect of tides on cusp growth and development (Coco *et al.,* in press*).*

An inverse model was compared with observations of nearshore circulation made during SandyDuck (Feddersen *et al.* 2004).

Models for bedload transport in two-phase sheet flow were developed, and tested with observations of morphological change (Hsu *et al., in review*).

As part of NCEX, over 100 sensors were deployed offshore, near, and onshore of two submarine canyons (Figure 1). In addition, bathymetric surveys extending from above the shoreline to about 8-m water depth were conducted almost weekly along several km of the coast. The survey data have been processed, and are available to the public on the WWW (cdip.ucsd.edu/models/ncex/bathy/ and science.whoi.edu/users/elgar/NCEX/maps/bathymetry2.html.

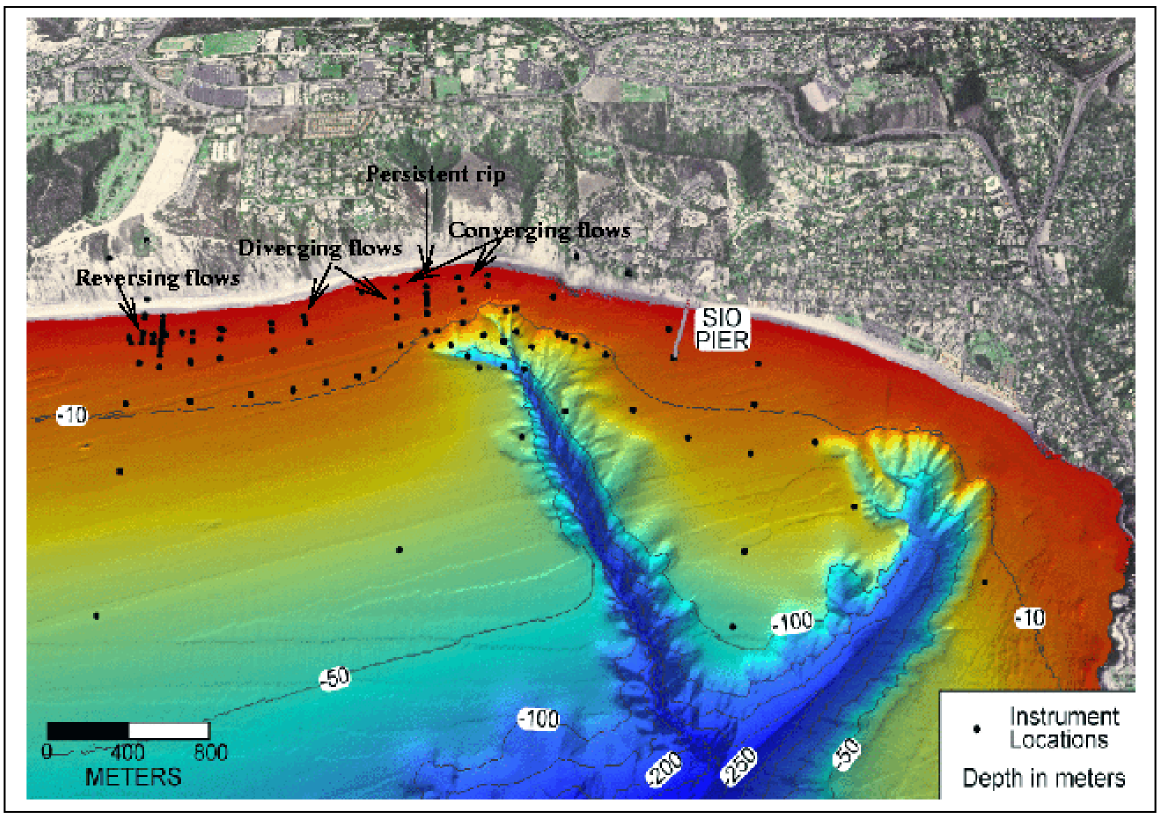

Figure 1. The NCEX instrument array (symbols) and bathymetry (contours are m relative to mean sea level). Arrows indicate circulation features observed when swell arrived from the south. The locations of rip currents, diverging and converging flows, and the cross-shore structure of alongshore currents in the swash and surf zones were different for different offshore wave fields (eg, Figures 3 and 4). [Instruments were deployed at over 100 locations offshore, near, and mostly onshore of two submarine canyons.]

RESULTS

Shear waves (instabilities of the breaking-wave-driven mean alongshore current) contribute to velocity fluctuations in the infragravity frequency band ($0.001 < f < 0.050$ Hz). Using 5 alongshore arrays of pressure gages and current meters deployed during SandyDuck, it was shown that in some cases the observed cross-shore structure of shear waves is similar to predictions based on linear stability theory. In other cases, shear wave energies are not consistent with this theory, suggesting the importance of neglected nonlinear effects (Noyes *et al*., 2004, Noyes *et al. in review*).

Inverse modeling of the circulation observed during SandyDuck allows independent estimation of the spatial variation of bottom friction and wave-breaking effects (Feddersen *et al.* 2004).

A surfzone drifter that can measure near-surface flows was developed by SIO PhD student William Schmidt (Schmidt*, PhD dissertation*). Laboratory and field tests demonstrate that the drifter follows near-surface particles that are not entrained in bores, and is not affected greatly by wind. Drifter deployments showed slowly rotating eddies located near the surfzone edge of time-variable rip currents, and surfzone circulation patterns that are consistent with simulations of numerical models based on the nonlinear shallow water equations (Schmidt *et al., in review*). The drifters were deployed on 4 days during NCEX.

Initial processing of surf and swashzone measurements suggests that NCEX data quality is excellent, and a database of wave heights, wave directions, wave-orbital velocities, and mean currents has been constructed. A wide range of wave conditions was observed, including 2-m high offshore waves, and cross- and alongshore surfzone mean currents exceeding 40 and 75 cm/s, respectively (Figure 2).

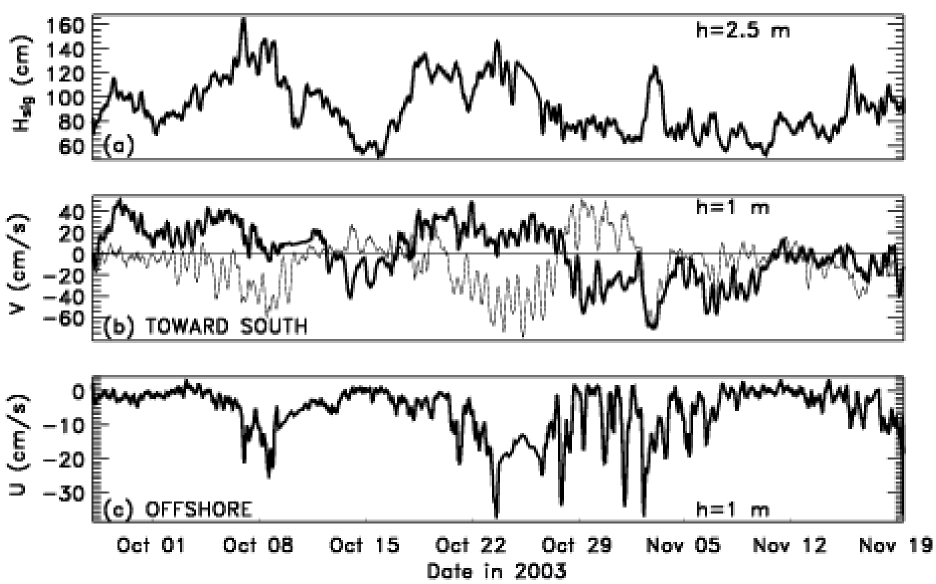

Figure 2. (a) Significant wave height observed in 2.5 m depth south of the bowl at Black's Beach, (b) mean alongshore current observed in 1.0 m depth south (thick curve) and north (thin curve) of the bowl, and (c) mean cross-shore current observed in 1.0 m depth south of the bowl versus time. Wave heights and cross-shore currents were similar north and south of the bowl. [The time series of currents show that alongshore flows on either side of the 450-m wide bowl usually were in opposite directions.]

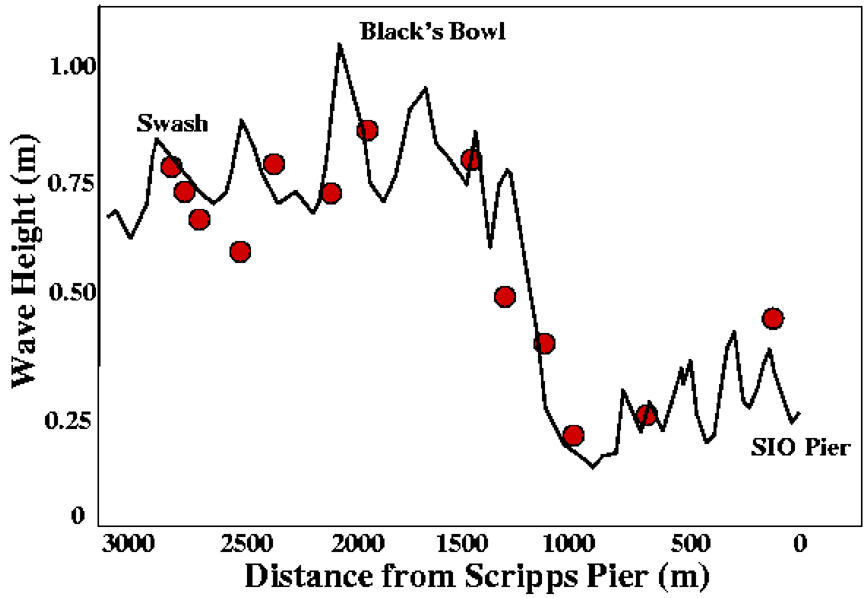

Figure 3. Wave height versus distance from the Scripps (SIO) Pier. The curve is spectral-refraction model predictions (W. O'Reilly) of 15 s waves arriving from the northwest, and the symbols are the heights of 15 s waves with the same offshore direction observed in 5 m depth on Oct 22, 1600 hrs. [The model predicts the observed wave heights, which ranged from 0.25 to 0.80 m along 3 km of coast.]

As predicted, the abrupt canyon bathymetry produces strong alongshore changes in wave height (Figure 3) and direction (not shown), driving complicated circulation. For example, flows at locations separated 450 m alongshore often were in opposite directions (compare thin and thick curves in Figure 2b). When offshore waves approached the coast from the northwest, the flows converged toward the 'bowl' at Black's Beach (Oct 22 in Figure 2b, and Figure 4a), whereas when waves approached from the south, flows diverged across the bowl (Oct 29 in Figure 2b, and Figure 4b).

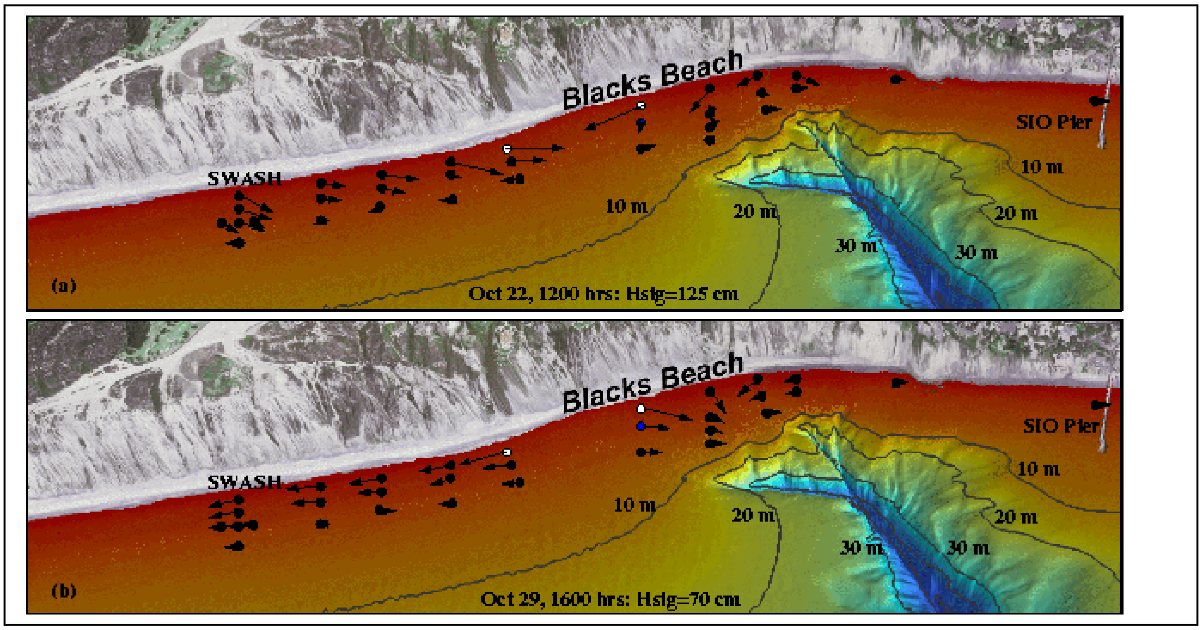

Figure 4. Circulation observed during NCEX when (a) 125-cm high waves were incident from the northwest [flows converged in the bowl] and (b) 70-cm high waves were incident from the south [flows diverged across the bowl]. Depth contours are labeled in m below mean sea level. Vectors (largest are about 50 cm/s) indicate direction and strength of 1-hr mean currents. Time series of mean alongshore currents for the sensors with white circles (on either side of the bowl at Black's Beach) are shown in Figure 2b, and the time series of significant wave height from the sensor with a blue circle (south side of the bowl) is shown in Figure 2a. [Flows onshore of the canyon head often caused an offshore-flowing rip current, approximately centered on the transect of 4 sensors between the canyon and the shoreline.]

On 4 days, Lagrangian drifters repeatedly were deployed along cross-shore transects extending from the inner surf zone to a few hundred m offshore within the area shown in Figure 4. Circulation patterns from the drifter trajectories will be used to estimate the locations, flow speeds, and offshore extents of rip currents, and will augment observations acquired with the array of in situ sensors. In addition to the instruments deployed in depths 10 m that are concentrated onshore of Scripps Canyon (Figure 4), pressure gages and current meters were deployed in 10-, 15-, and 20- m depths near the canyons, and in a cross-shelf array extending from 30-m depth to the shoreline at the north end of the study area (Figure 1). Collaborative studies will include comparison of observations with model predictions of waves propagating across the canyons, and of the generation and propagation of infragravity waves.

IMPACT/APPLICATIONS

The field observations have been used to verify and improve models for nearshore and surfzone waves, circulation, and morphological change. The comparison of model predictions with observations has increased our ability to predict nearshore bathymetric change, including the migration of sandbars across the surfzone.

RELATED PROJECTS

The Duck94 and SandyDuck observations of nearshore waves, currents, and bathymetry are being used to test components of the NOPP nearshore community model, as well as several models for nearshore sediment transport and morphological change,.

The studies of nearshore morphology are in collaboration with an Army Research Office project to investigate onshore sediment transport and sandbar migration.

Surfzone drifters are being developed in collaboration with a Sea Grant project.

Observations of nearshore bedforms are being used as part of Mine Burial Program studies (with E. Gallagher).

NCEX observations are being used in collaboration with modeling studies and as ground truth for remote sensing of nearshore currents.

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